

### 3.4 RISER POLE 14101 SITE

#### 3.4.1 Measurement Conditions

The riser pole for Feeder 14101 was selected for the second set of measurements because of its close proximity to the PEPCO Tuxedo substation and the underground feeder cable serving the WMATA rectifier load. Also, the site provided data at the input of Feeder 14101. This distribution line contained the Prince George's Country Club and the Landover Road sites.

The measurement van was placed directly under the PEPCO 13.8 kV distribution line identified as Feeder 14101. The site was located immediately adjacent to a small industrial area which included a large Safeway store's bakery plant. Several of the industrial firms were believed to be candidates for background noise sources.

A log of the various actions taken during the Riser Pole 14101 site measurements are given in Table 3. This log provides a convenient reference to the sequence of operations and the status of the PEPCO and WMATA systems. All data on system performance measurements provided in subsequent paragraphs can be related to this log.

Measurement system parameters for the various 3-axis views taken at the Riser Pole 14101 site are summarized in Table 4. These parameters will be useful to those individuals who wish to scale the 3-axis views for some specific detail. The 3-axis views can be related to Tables 3 and 4 by date and time of day or with the figure number provided in each table.

Data was taken at the Riser Pole 14101 site on 10/25/78 from about 0800 to 1130 hours local time.

Table 3  
RISER POLE 14101 SITE ACTIVITY

McGraw-Edison Item No.	LOCAL TIME	DATE	CAPACITOR BANK STATUS	TRAIN STATUS	3-AXIS FIGURE NUMBER
9A	0947	10/25/78	All Cap. Banks Out	Train Run	14
10A	1005	10/25/78	1500 kVAR Cap. Bank on Feeder 14101 Switched In	Off	—
11A	1013	10/25/78	1500 kVAR Cap. Bank In - All Others Out	Train Run	—
12A	1037	10/25/78	12 MVAR Tuxedo Substation Cap. Bank Switched In	Off	15
13A	1043	10/25/78	12 MVAR Cap. Bank In	Train Run	16

Table 4  
MEASUREMENT SYSTEM PARAMETERS, RISER POLE 14101

3-AXIS FIGURE NUMBER	DATE	LOCAL TIME	ANTENNA TYPE	LOOP FREQ. kHz	CENTER FREQUENCY kHz	FREQ. WIDTH kHz	IF BAND- WIDTH kHz	SCAN TIME ms	IF REF dB	RF REF dB	TYPE OF DATA
11	10/25/78	1130	Loop	40-150 T50	50	20	1	100	-10	0	Background
12	10/25/78	1110	Loop	40-150 T100	100	50	1	100	-20	0	Background
13	10/25/78	1124	Loop	40-150 T100	100	20	1	50	-10	0	Background
14	10/25/78	0946	Loop	10-40 T30	14	20	1	100	-10	0	System
15	10/25/78	1037	Loop	10-40 T30	14	20	1	100	-10	0	System
16	10/25/78	1042	Loop	10-40 T30	14	20	1	100	-10	0	System

### 3.4.2 Ambient Measurements

The background noise levels on Feeder 14101 were examined at the riser pole prior to WMATA train measurements. The rectifier was idled across the PEPCO system source without train loads during all background measurements.

Significant background noise was found emanating from Feeder 14101 in the vicinity of the riser pole; examples are given in Figures 11 through 13. Noise levels at the 40 to 60 kHz frequency range were defined in Figure 11. A continuous wave signal was found at 52 kHz whose source was not identified. Noise in the 50 to 60 kHz range was impulsive with a well defined period of 2.8 ms. Noise below 50 kHz also appeared to have a primary period of 2.8 ms. The 2.8 ms period suggested a three-phase source with both positive and negative switching on all three phases. Non-flat amplitude vs. frequency properties can be seen in the upper view of Figure 11.

Background noise in the 75 to 125 kHz frequency range had an entirely different time domain structure as shown in Figure 12. The double hook-like structure suggested that an impulse noise source existed whose trigger point varied with voltage. The impulse intervals implied that a three-phase source was responsible for the unique and variable time domain structure. The upper view of Figure 12 shows well defined amplitude vs. frequency shapes related to the structure in the bottom view.

Background noise in the 90 to 110 kHz frequency range was examined at a lower scan time than used for the previous two sets of views when a large change in background was noted (see Figure 13). A three-phase impulse source triggering at a fixed period on both the positive and negative portions of the 60 Hz waveform was turned on at 1.6 seconds down the time scale and remained on for some time. Such changes in background complicated the task of defining the background noise, and they made field personnel keenly aware of the nonstationary characteristics of the impulsive noise as well as the relationship between the

observed noise and one or two predominant sources responsible for most noise conditions.

### 3.4.3 System Measurements

Measurements at Riser Pole 14101 were made to search for rectifier noise as WMATA trains were operated and as various capacitors were switched on. The 3-axis views in Figure 14 were taken with all capacitors switched out and as a train was started. Background noise can be seen throughout the views. In addition a small increase in impulsive noise can be seen at the 8 to 12 kHz frequencies which was associated with train start-up. The impulsive noise was synchronous with the 60 Hz power line frequency. A primary period of 8.3 ms was present as well as other smaller impulse periods clustered around each 8.3 ms interval. This measurement was the first observation of detectable noise from the rectifier.

A second train run with the 1500 kVAR capacitor bank on Feeder 14101 switched in gave inconclusive results.

In Figure 15 the train was off and the Tuxedo 12 MVAR capacitor bank was switched from off to on. A capacitor switching transient can be seen in the lower view at about 5 seconds on the time axis. The strong impulses exceeding the general noise amplitude level in the upper view were the capacitor switching transients. No measurable change in the general background noise occurred when the substation capacitor bank was switched into the circuit.

In Figure 16 the 12 MVAR Tuxedo substation capacitor bank was on and the train was started at the indicated time. No measurable noise change was found at train start. The background noise had changed somewhat from that in Figure 14, the view where train-associated noise was found. This change in background noise was not sufficient to blank out or override the train noise found in Figure 14. Apparently, the 12 MVAR substation capacitor effectively bypassed any increased noise from the rectifiers caused by train operation.

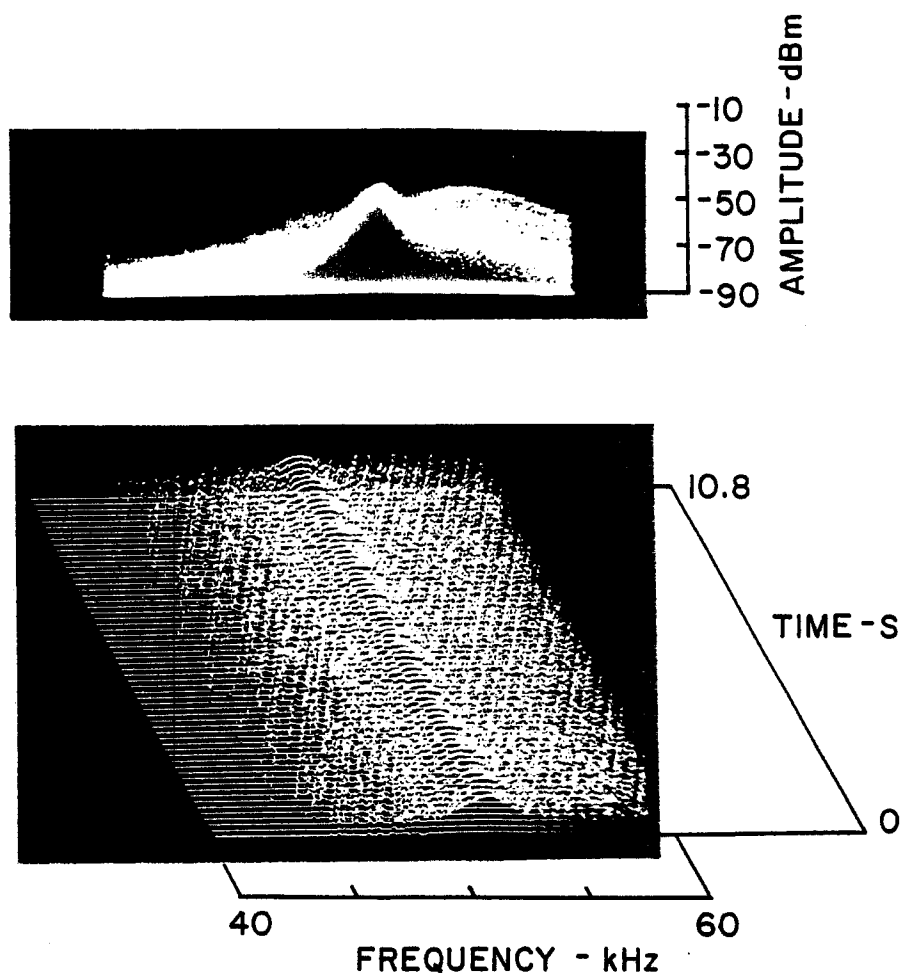


Figure 11 14101 Riser Pole Site, 10/25/78, 1130

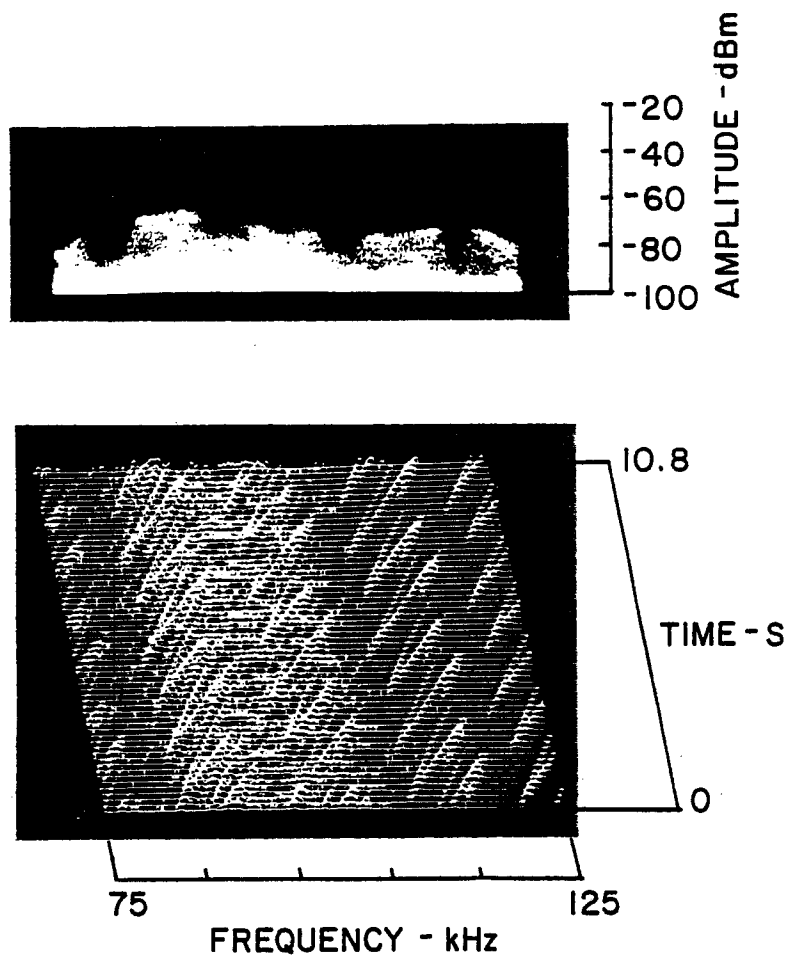


Figure 12 14101 Riser Pole Site, 10/25/78, 1110

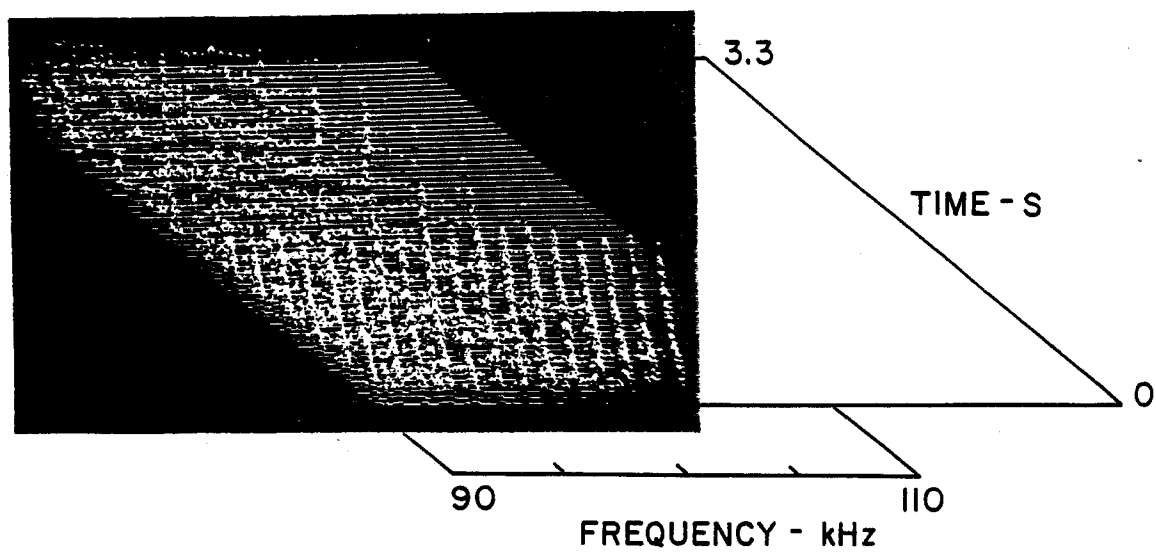


Figure 13 14101 Riser Pole Site, 10/25/78, 1124

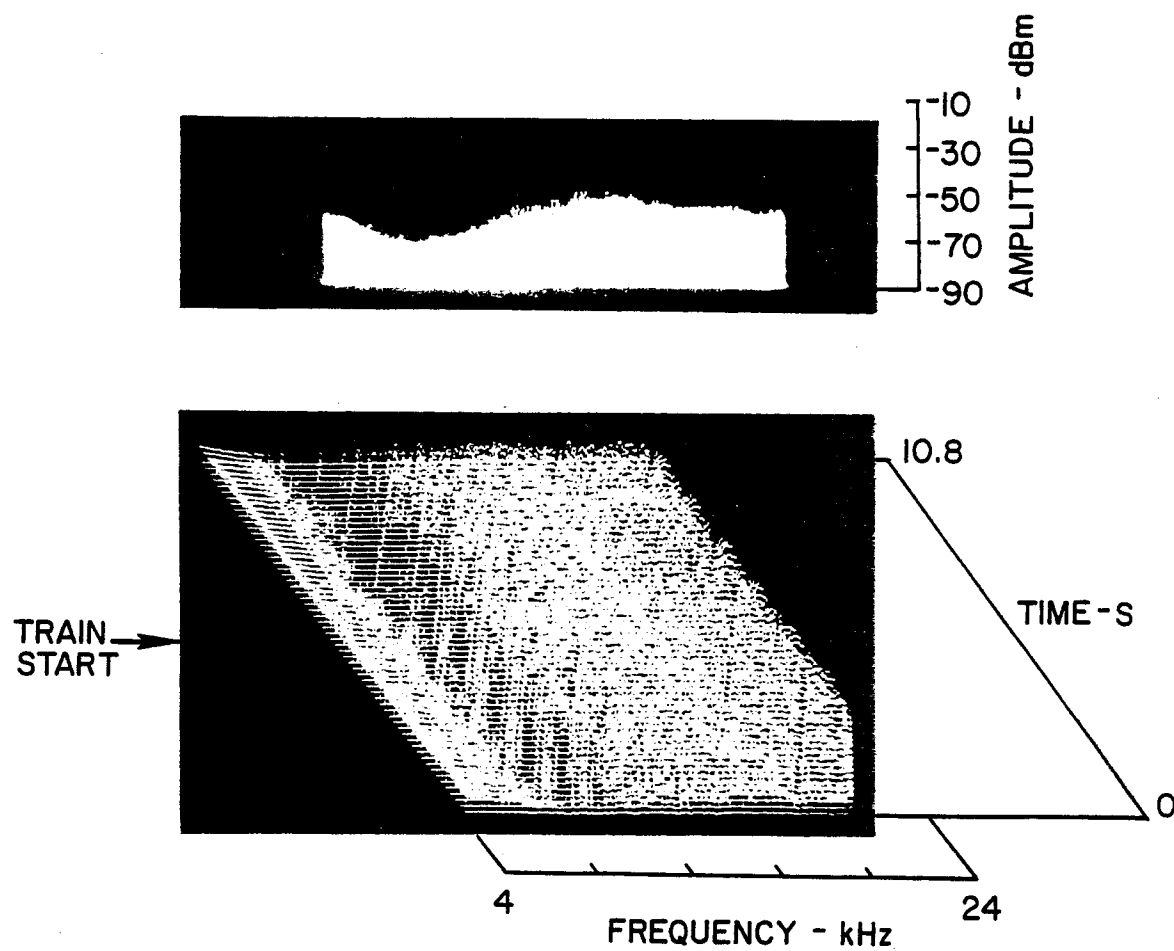


Figure 14 14101 Riser Pole Site, 10/25/78, 0946

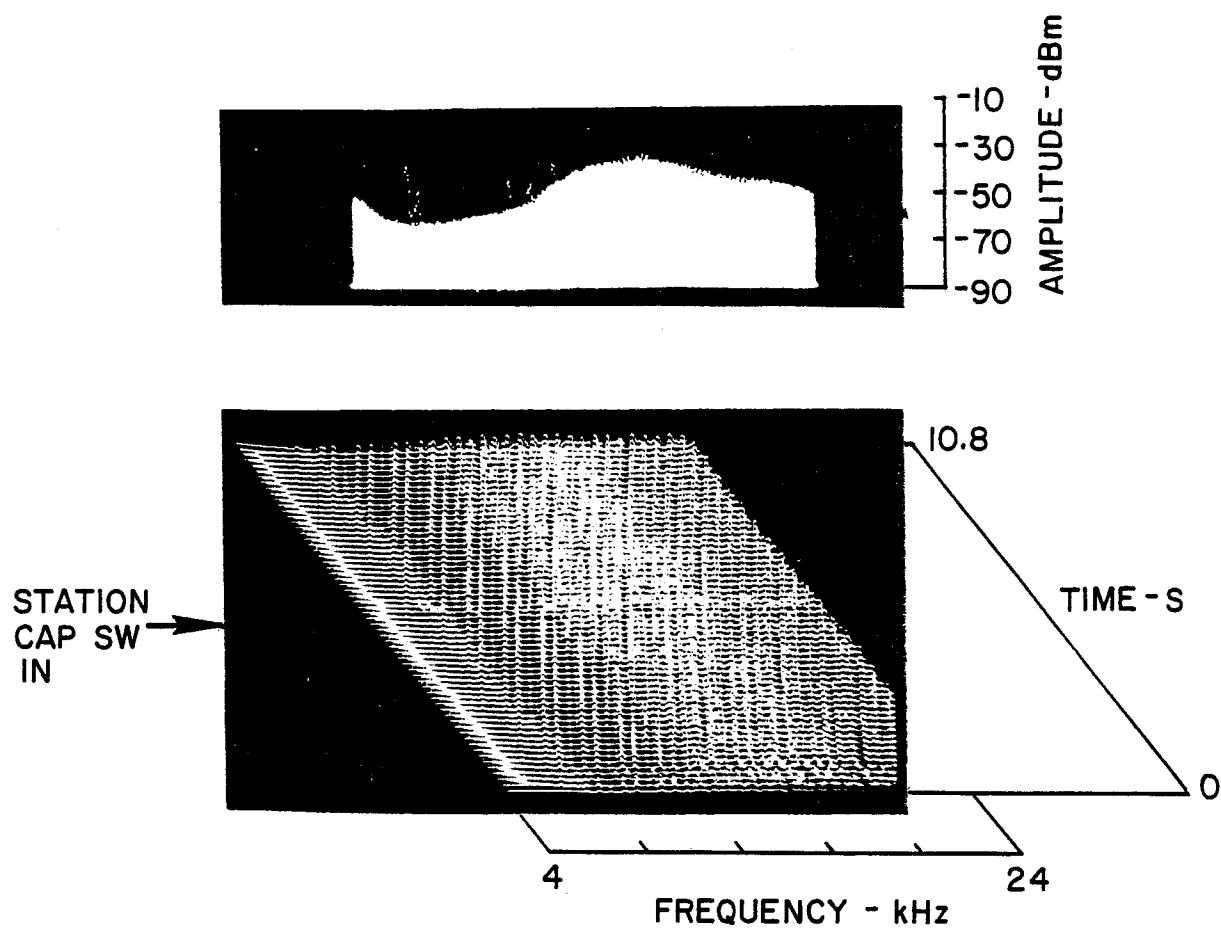


Figure 15 14101 Riser Pole Site, 10/25/78, 1037

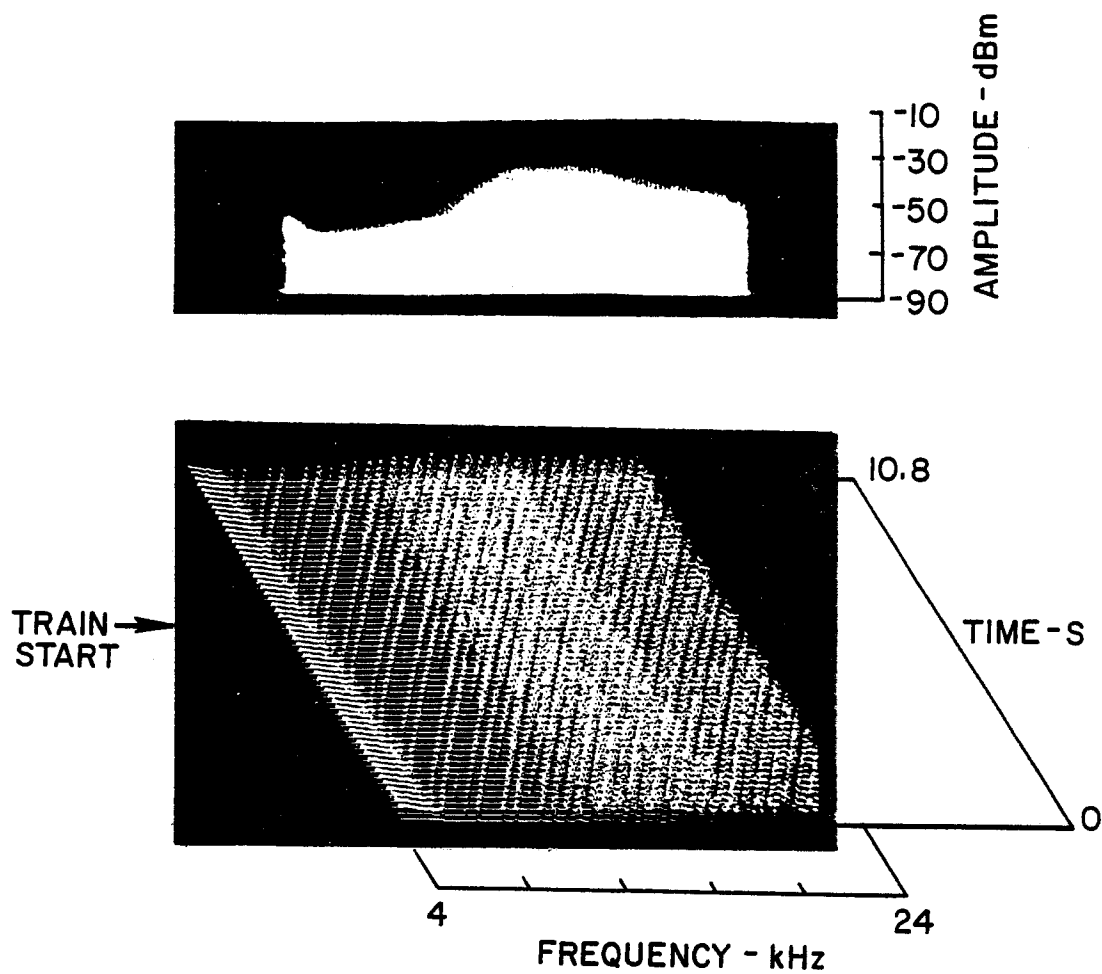


Figure 16 14101 Riser Pole Site, 10/25/78, 1042

### 3.5 PRINCE GEORGE'S (P.G.) COUNTRY CLUB SITE

#### 3.5.1 Measurement Conditions

A site along the edge of the P.G. Country Club golf course was selected for the third set of measurements. The site was located in a rural area with an occasional low density housing complex. The site was free of nearby buildings and other structures.

The P.G. Country Club site was on Feeder 14101, and it was located 4.6 kft from the Riser Pole 14101 site. The measurement van was placed directly under the 13.8 kV distribution line (Feeder 14101). The loop-stick antenna was the primary inductive field sensor employed at the site.

A log of the various actions taken during the P.G. Country Club site measurements is given in Table 5. This log provides a convenient reference to the sequence of operations and the status of the PEPCO and WMATA systems. All data on system performance measurements provided in subsequent paragraphs can be related to this log.

Measurement system parameters for the various 3-axis view taken at the P.G. Country Club site are summarized in Table 6. These parameters will be useful to those individuals who wish to scale the 3-axis views for some specific detail. The 3-axis views of WMATA/PEPCO systems measurements can be related to Tables 5 and 6 by date and time of day or with the figure number provided in each table.

Data was taken at the P.G. Country Club site on 10/25/78 from about 1230 to 1700 hours local time.

Table 5  
P.G. COUNTRY CLUB SITE ACTIVITY

McGRAW- EDISON ITEM NO.	LOCAL TIME	DATE	CAPACITOR BANK STATUS	TRAIN STATUS	3-AXIS FIGURE NUMBER
14B	1313	10/25/78	All Cap. Banks Out	Train Run	21
15B	1341	10/25/78	1500 kVAR Cap. Bank on Feeder 14101 Switched In	Off	23
16B	1353	10/25/78	1500 kVAR Cap. Bank In	Train Run	24
17B	1401	10/25/78	1500 kVAR Cap. Bank Left In and 1200 kVAR Cap. Bank on Feeder 14101 Switched In	Off	—
18B	1417	10/25/78	1500 kVAR and 1200 kVAR Cap. Banks In	Train Run	25
19B	1431	10/25/78	1500 kVAR and 1200 kVAR Cap. Banks Switched Off and Then 12 MVAR Tuxedo Substation Cap. Bank Switched In	Off	26
20B	1443	10/25/78	12 MVAR Cap. Bank In	Train Run	27
21B	1447	10/25/78	1500 kVAR Cap. Bank on Feeder 14101 Switched In	Off	—
22B	1453	10/25/78	12 MVAR and 1500 kVAR Cap. Banks In	Train Run	—

Table 6  
MEASUREMENT SYSTEM PARAMETERS, P.G. COUNTRY CLUB

3-AXIS FIGURE NUMBER	DATE	LOCAL TIME	ANTENNA TYPE	LOOP FREQ. kHz	CENTER FREQUENCY kHz	FREQ. WIDTH kHz	IF BAND- WIDTH kHz	SCAN TIME ms	IF REF dB	RF REF dB	TYPE OF DATA
17	10/25/78	1252	Loop	10-40 T10	14	20	1	100	-10	0	
18	10/25/78	1258	Loop	10-40 T15	15	10	1	100	-10	0	
19	10/25/78	1241	Loop	40-150 T50	50	20	1	100	-20	0	
20	10/25/78	1228	Loop	40-150 T100	100	100	1	100	-20	0	
21	10/25/78	1313	Loop	10-40 T10	8	10	1	100	-10	0	
22	10/25/78	1314	Loop	10-40 T10	8	10	1	100	-10	0	
23	10/25/78	1341	Loop	10-40 T10	14	20	1	100	-10	0	
24	10/25/78	1353	Loop	10-40 T10	5	10	1	100	-10	0	
25	10/25/78	1418	Loop	10-40 T10	8	10	1	100	-10	0	
26	10/25/78	1431	Loop	10-40 T10	14	20	1	50	-10	0	Scan Sync to 60 Hz line
27	10/25/78	1444	Loop	10-40 T10	8	10	1	100	-10	0	

### 3.5.2 Ambient Measurements

The background noise levels at the P.G. Country Club site on Feeder 14101 were examined prior to WMATA train measurements. The rectifier was idled across the PEPCO system without train loads during these measurements.

Background noise conditions at the 4 to 150 kHz frequencies are portrayed in Figures 17 through 20. The 4 to 24 kHz segment of the overall range was examined in Figure 17. A noise maximum was found at 10 kHz, the center frequency of the loop antenna filter. There is evidence of another peak in the impulsive noise at 4 to 5 kHz. This peak was not defined because it was below the tuning range of the loop antenna. A continuous wave signal can be seen at about 22 kHz.

The 10 to 20 kHz portion of Figure 17 was expanded to better show noise detail in Figure 18. Apparently either two or more sources were involved in producing the complex timing patterns, or it was a three-phase source with unequal impulse current per phase.

Impulsive noise in the 40 to 60 kHz frequency range is shown in Figure 19. A continuous wave signal at 52 kHz prevented a complete examination of the band; however, complex impulsive timing patterns can be seen above and below the CW signal. Groups of three impulses can be seen which are spread 8.3 ms apart. Another single impulse can be seen between the groups of three.

Noise in the 50 to 150 kHz frequency band is shown in Figure 20. Complex v shapes are shown at distinct frequencies. These patterns suggest that one or more sources of impulsive noise existed whose trigger point on the 60 Hz power line waveform varied with time. A continuous wave signal was found at 137 kHz.

### 3.5.3 System Measurements

Measurements at the P.G. Country Club were made to observe and define rectifier noise as WMATA trains were operated and as various capacitors were switched on. In Figure 21 rectifier noise is shown with all capacitors off and as the train started. A very clear and distinctive signature of the rectifier noise appeared immediately upon train start. Groups of four or five impulses were spaced 8.3 ms apart. This pattern suggested that one phase section of the rectifier was responsible for most of the radiated signal where this phase had multiple impulse firing times with respect to the 60 Hz waveforms.

Of special interest is that the rectifier slanting lines were at a slightly different slant angle across the bottom view of Figure 21 than the background noise. This suggests that the two impulsive noise sources (rectifier and background) had slightly different frequencies. The reason for this observation is unknown.

Figure 22 was taken very shortly after Figure 21, and it shows rectifier noise as the train propulsion was turned off. The 3 to 10 kHz wide impulsive noise immediately stopped at the train off time noted in the view.

Figure 23 shows background noise when the train was off, all capacitor banks were off, and the 1500 kVAR capacitor bank on Feeder 14101 was switched in. A brief switching transient can be seen as well as a slight reduction in the level of the impulsive noise at the 10 to 18 kHz frequencies. This was the first observed case where background noise was affected by a capacitor switching operation.

In Figure 24 the 1500 kVAR capacitor bank on Feeder 14101 was on, all other capacitor banks were off, and the train was started. Two perspective views are shown as well as the amplitude vs. frequency views. The two perspective views show the same data but with a

lower threshold setting in the bottom view. Distinctive groups of five impulses were obtained where the groups were spaced 8.3 ms apart. The five impulses occurred in approximately 6 ms.

In Figure 25 the 1500 kVAR capacitor bank on Feeder 14101 was in, the 1200 kVAR capacitor bank on Feeder 14101 was in, all other capacitor banks were out, and the train was started at the time indicated in the bottom view. The rectifier noise was clearly observable, but the amplitude was slightly lower than found in Figures 22 and 24.

In Figure 26 the receiver scanning process was synchronized with the power line frequency, and the scan time was changed from the 100 ms value used in most previous views to 50 ms. The slanting lines then became synchronous with the scan process of the receiver, and these lines became vertical lines parallel to the time axis. In the top view the two strong impulses on the far left of the view were spaced 2.8 ms apart. The four lower level impulses to the right of the two strong impulses were also spaced 2.8 ms apart. At the indicated time the 1200 kVAR capacitor bank on Feeder 14101 was turned off. Switching transients can be seen as well as a new impulse between the two strong impulses. In the bottom view the 1500 kVAR capacitor bank on Feeder 14101 was turned off. Small switching transients are visible in the view as well as small changes in the impulse structure.

The synchronized scan presentation in Figure 26 was found to be useful when continuous wave signals were not present in a view. A view with unsynchronized scanning was always necessary to test for the absence of continuous wave signals before a synchronized scanning view was considered valid.

In Figure 27 the 12 MVAR Tuxedo substation capacitor bank was in, all other capacitor banks were out, and the train power was turned on at the time indicated in the view. The impulses were spaced at 2.8 ms intervals, which suggests a three-phase source with positive and negative

triggering. The large substation capacitor bank obviously changed the timing pattern by some unknown process from the pattern previously observed in Figures 21, 22, 24, and 25. The background noise at 10 to 13 kHz was not changed from that of the previous views by any significant amount.

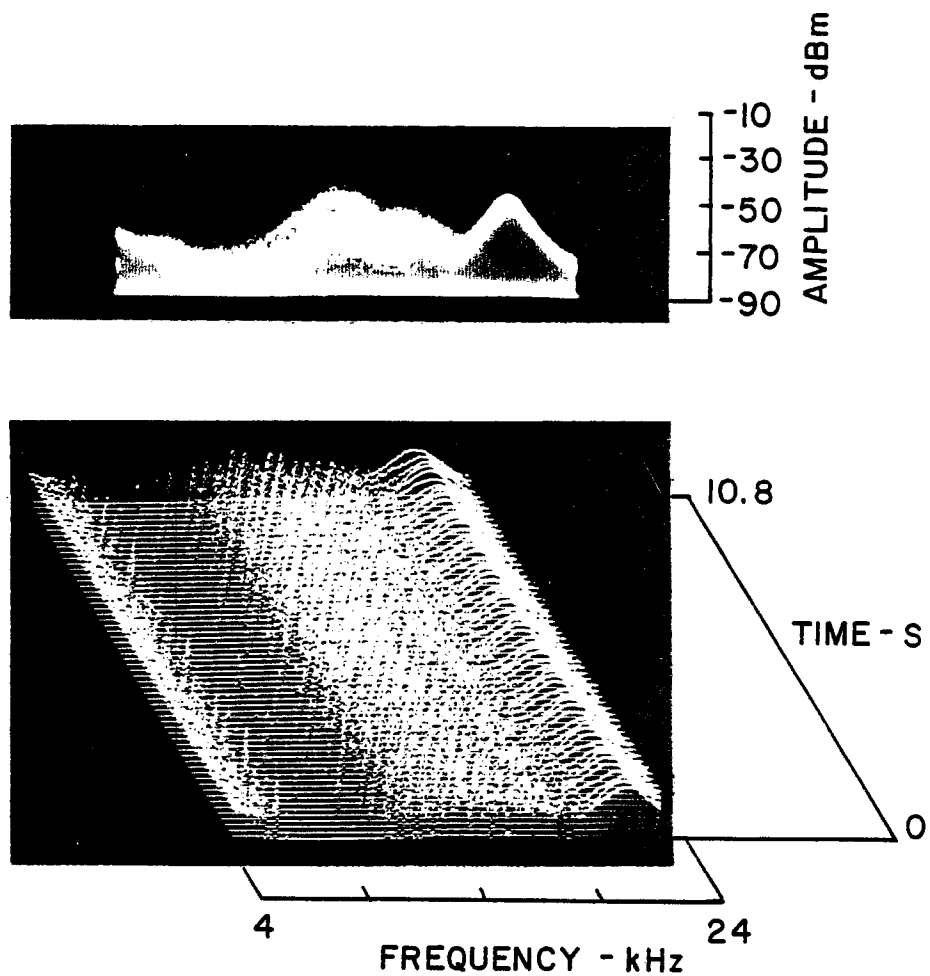


Figure 17 P.G. Country Club Site, 10/25/78, 1252

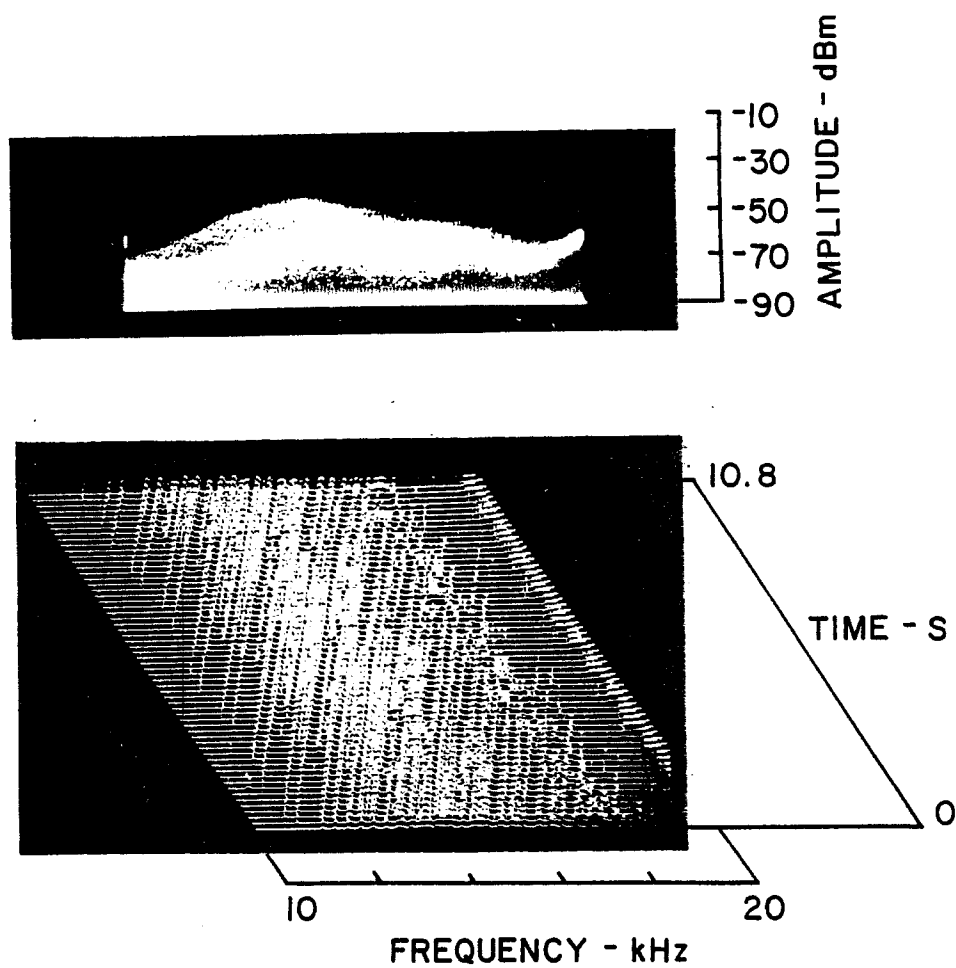


Figure 18 P.G. Country Club Site, 10/25/78, 1258

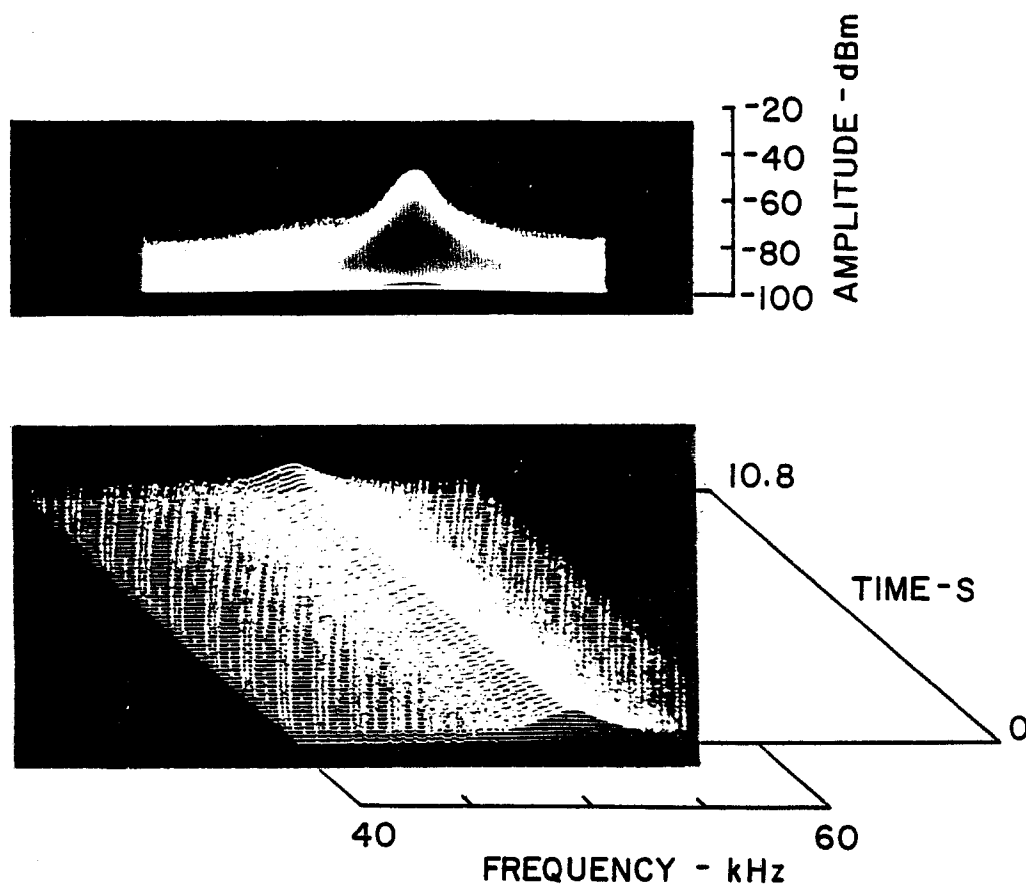


Figure 19 P.G. Country Club Site, 10/25/78, 1241

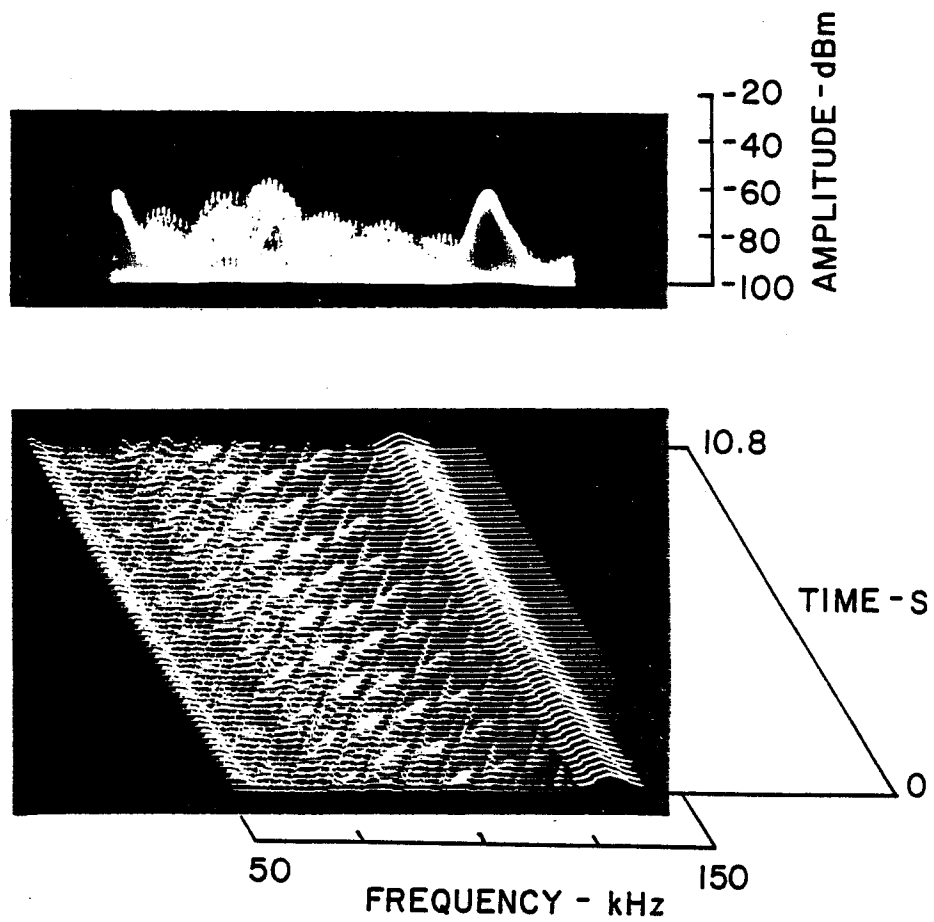


Figure 20 P.G. Country Club Site, 10/25/78, 1228

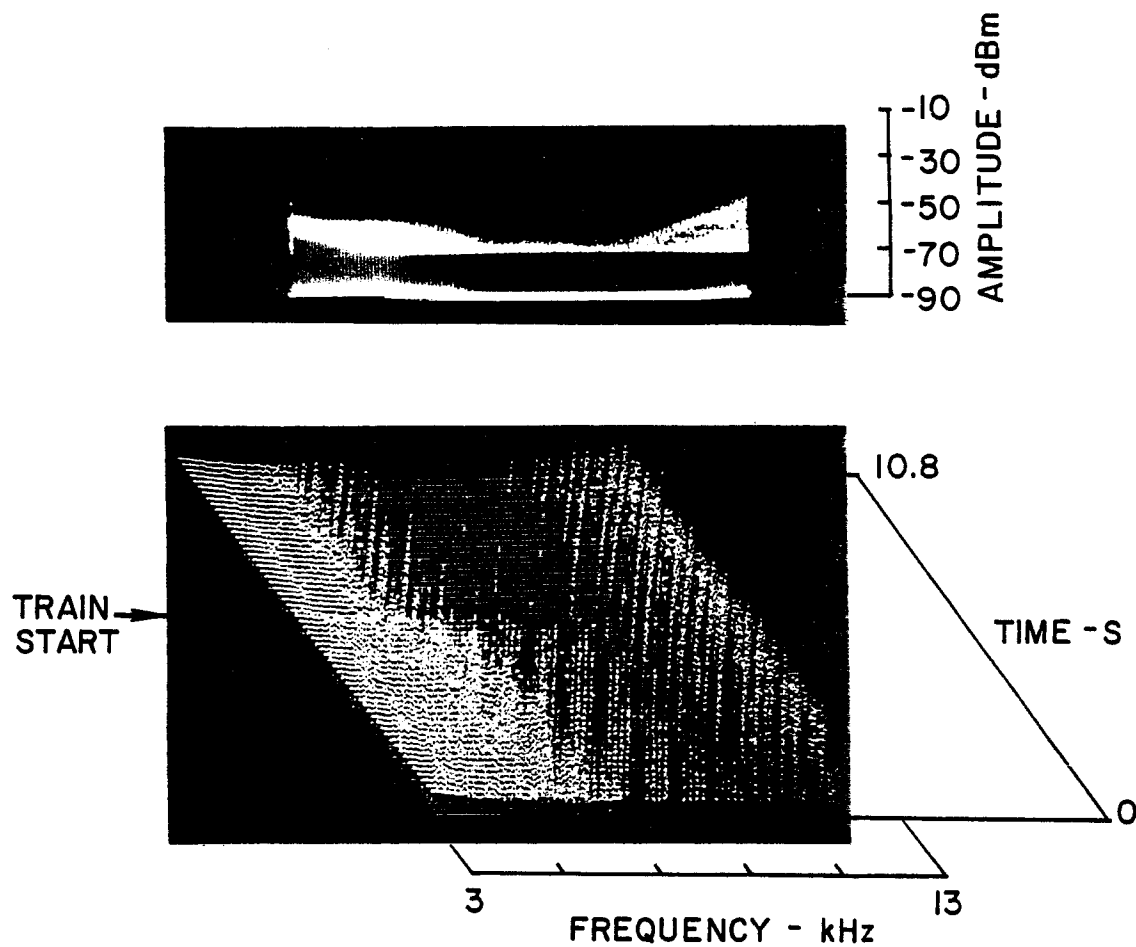


Figure 21 P.G. Country Club Site, 10/25/78, 1313

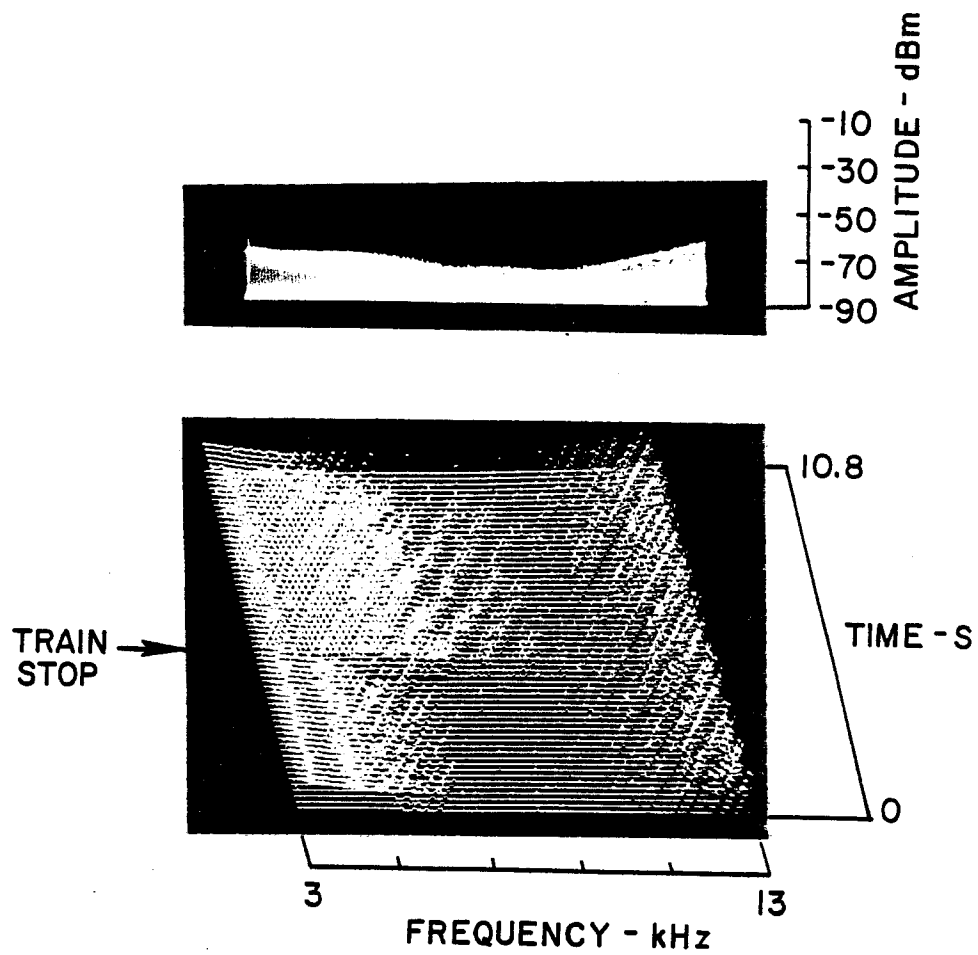


Figure 22 P.G. Country Club Site, 10/25/78, 1314

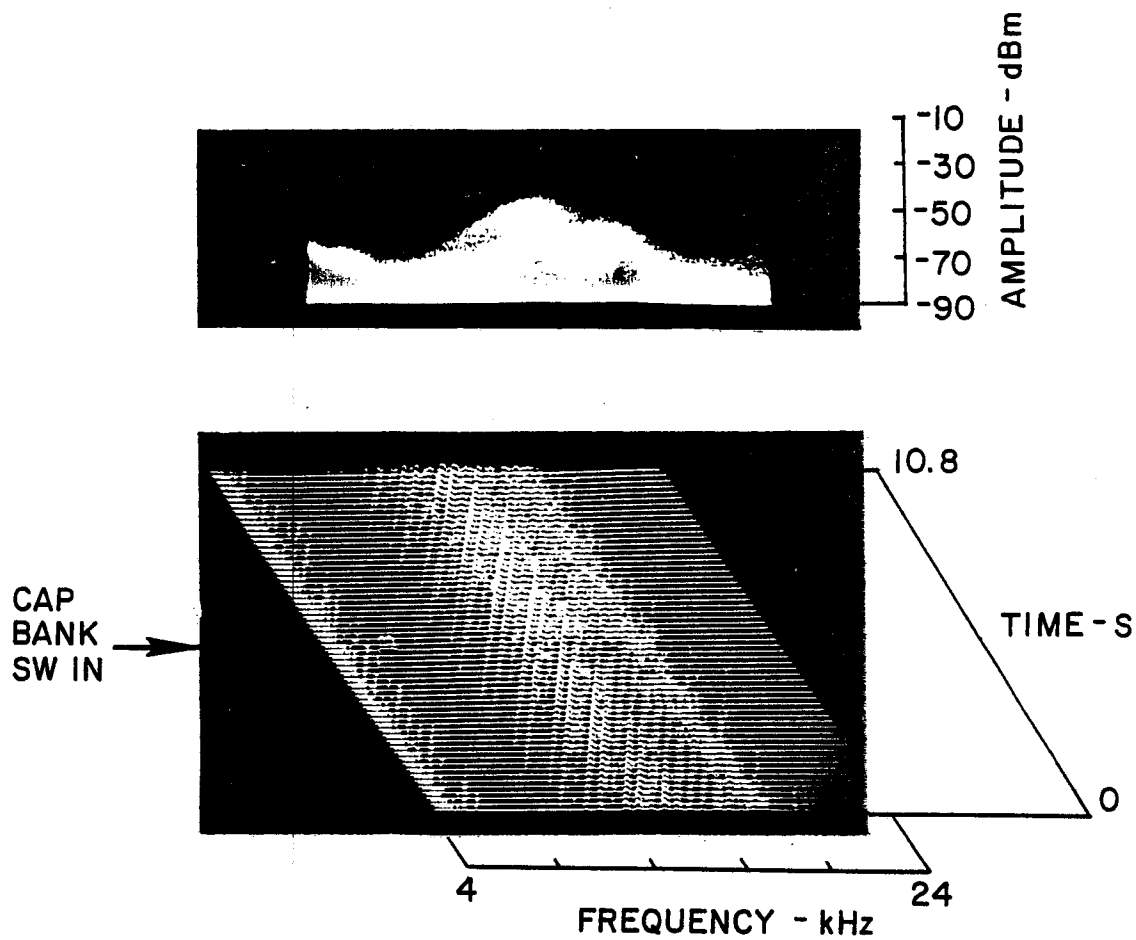


Figure 23 P.G. Country Club Site, 10/25/78, 1341

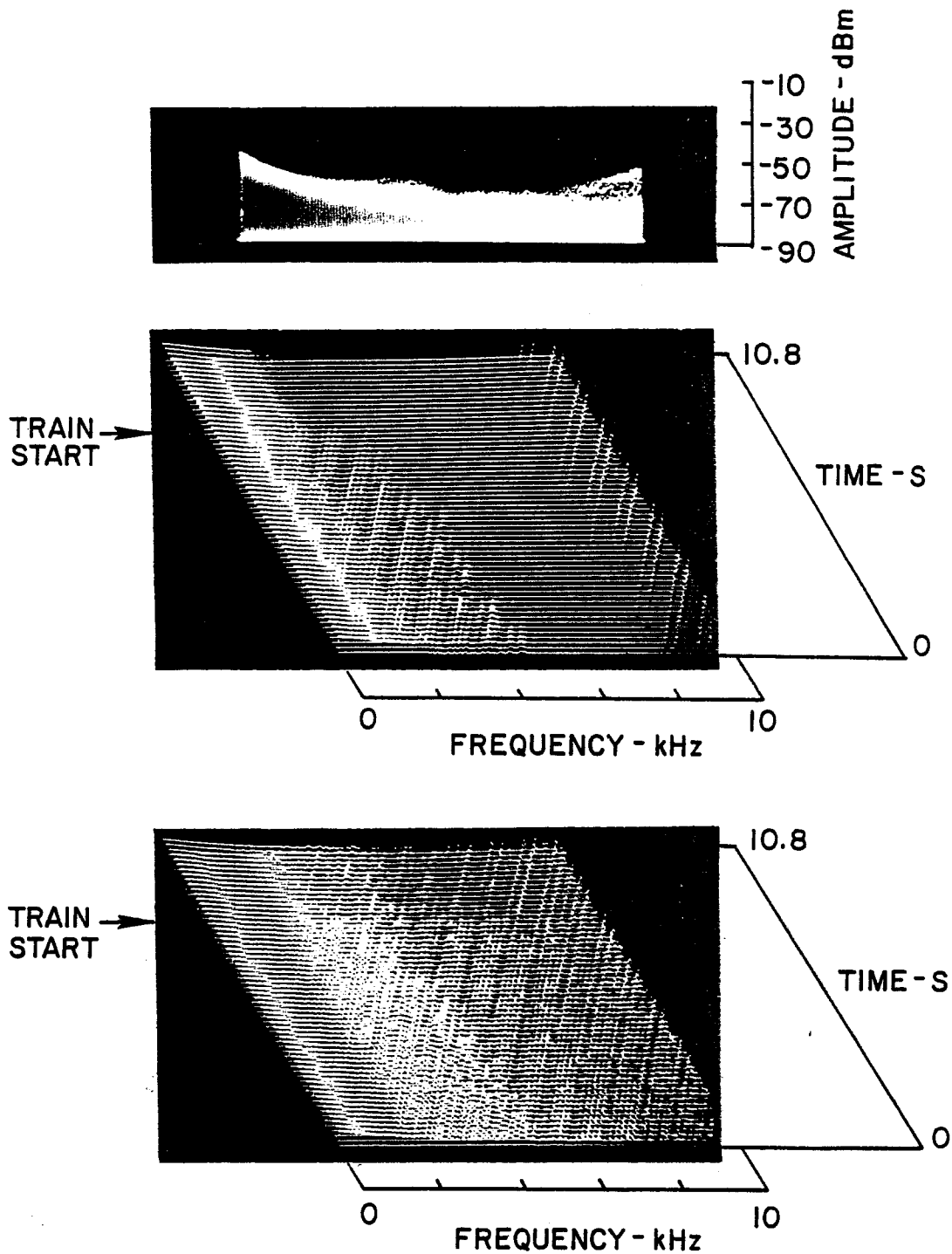


Figure 24 P.G. Country Club Site, 10/25/78, 1353

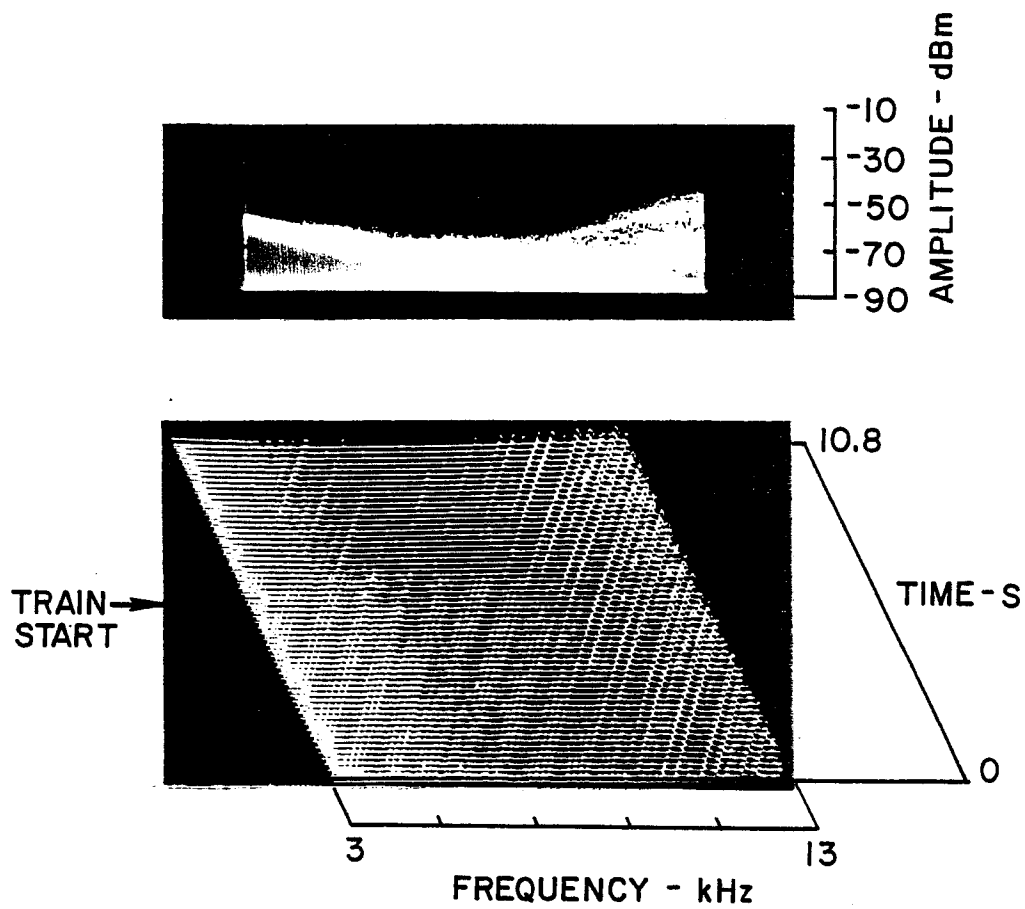


Figure 25 P.G. Country Club Site, 10/25/78, 1418

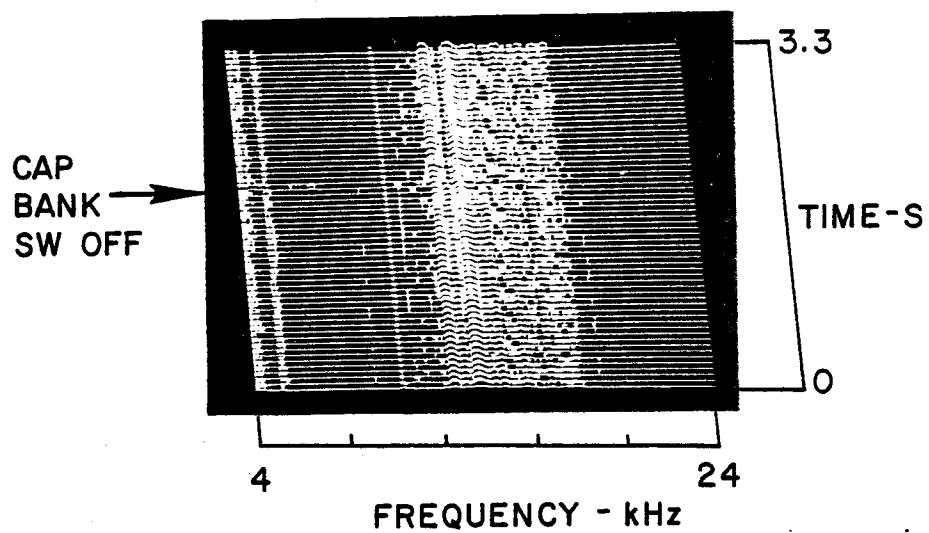
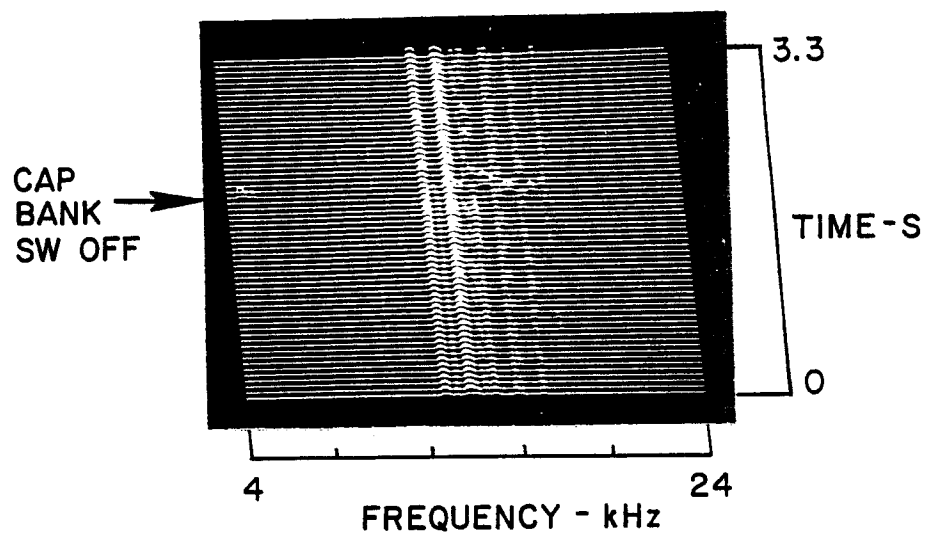


Figure 26 P.G. Country Club Site, 10/25/78, 1431

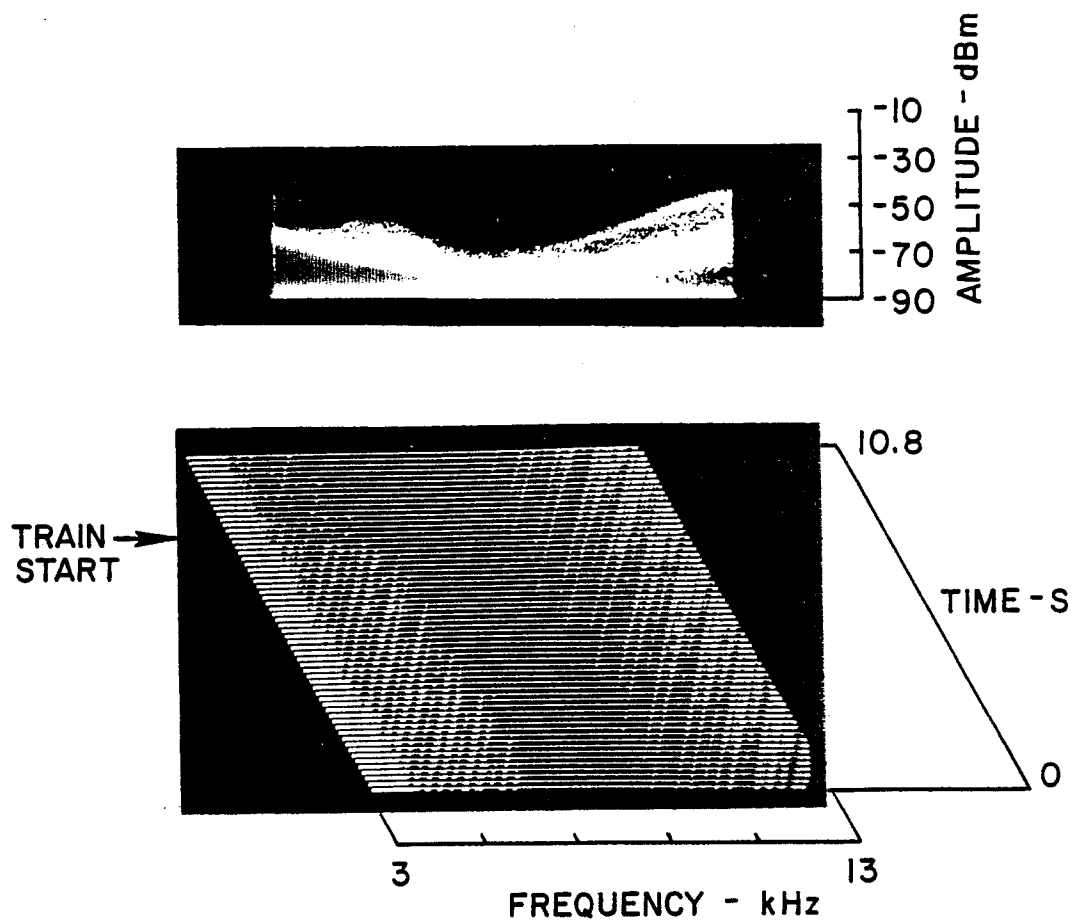


Figure 27 P.G. Country Club Site, 10/25/78, 1444

### 3.6 GREENLEAF AVENUE SITE

#### 3.6.1 Measurement Conditions

A site at the end of Greenleaf Avenue was selected for the fourth set of measurements. The site was located at the border of a quiet suburban residential area and a large undeveloped and wooded valley.

The Greenleaf Avenue site was on Feeder 14111 at a location 8 kft from the 14111 Riser Pole site. The measurement van was located directly under the 13.8 kV distribution line (Feeder 14111). Background measurements were made with the loopstick antenna sensor. System measurements were made with a direct connection to the McGraw-Edison 1000 to 1 voltage divider connected to the roadside feeder pair (Phase A).

A log of the various actions taken during the Greenleaf Avenue site measurements is given in Table 7. This log provides a convenient reference to the sequence of operations and the status of the PEPCO and WMATA systems. All data on system performance measurements provided in subsequent paragraphs can be related to this log.

Measurement system parameters for the various 3-axis views taken at the Greenleaf Avenue site are summarized in Table 7. These parameters will be useful to those individuals who wish to scale the 3-axis views for some specific detail. The 3-axis views of WMATA/ PEPCO systems measurements can be related to Tables 7 and 8 by date and time of day or with the figure number provided in each table.

Data was taken at the Greenleaf Avenue site on 10/26/78 from about 0730 to 1100 hours local time.

Table 7  
GREENLEAF AVENUE SITE ACTIVITY

McGraw- Edison Item No.	LOCAL TIME	DATE	CAPACITOR BANK STATUS	TRAIN STATUS	3-AXIS FIGURE NUMBER
24D	0926	10/26/78	All Cap. Banks Off	Train Run	—
25D	0947	10/26/78	600 kVAR Cap. Bank on Feeder 14111 Switched In	Off	32
26D	0951	10/26/78	600 kVAR Cap. Bank In	Train Run	—
27D	1000	10/26/78	12 MVAR Cap. Bank at Tuxedo Substation Switched In	Off	33(a)
28D	1005	10/26/78	12 MVAR Cap. Bank In	Train Run	33(b)
29D	1011	10/26/78	1200 kVAR Cap. Bank on Feeder 14111 Switched In	Off	—
30D	1021	10/26/78	1200 kVAR Cap. Bank In	Train Run	—

Table 8  
MEASUREMENT SYSTEM PARAMETERS, GREENLEAF AVENUE

3-AXIS FIGURE NUMBER	DATE	LOCAL TIME	ANTENNA TYPE	LOOP FREQ. kHz	CENTER FREQUENCY kHz	FREQ. WIDTH kHz	IF BAND- WIDTH kHz	SCAN TIME ms	IF REF dB	RF REF dB
28	10/26/78	0804	Loop	10-40 T10	14	20	1	100	-10	0
29	10/26/78	0809	Loop	10-40 T40	50	50	1	100	-10	0
30	10/26/78	0814	Loop	40-150 T100	100	50	1	100	-10	0
31	10/26/78	0820	Loop	150-500 T200	200	50	1	100	-10	0
32	10/26/78	0947	Phase A/V	—	14	20	1	100	-10	0
33(a)	10/26/78	1000	Phase A/V	—	14	20	1	100	-10	0
33(b)	10/26/78	1004	Phase A/V	—	14	20	1	100	-10	0

### 3.6.2 Ambient Measurements

The background noise levels on Feeder 14111 at the Greenleaf Avenue site were examined prior to WMATA train measurements. The rectifier was idled across the PEPCO system without train loads during these measurements.

Background noise at the 4 to 24 kHz frequencies is shown in Figure 28. The noise characteristics at the Greenleaf Avenue site were similar to those found at other sites (see Figure 15 for the Riser Pole 14101 site, Figure 17 for the P.G. Country Club site, and Figure 34 for the Pinebrook/Landover site).

Background noise in the 25 to 75 kHz band is shown in Figure 29. In the 25 to 65 kHz portion of the view a primary impulse period of 8.3 ms was found which contained secondary impulsive structure. The secondary structure fell below the threshold level of the view at about 65 kHz, and the primary impulses spaced 8.3 ms apart were predominant over the 65 to 75 kHz portion of the view. The amplitude vs. frequency variations are shown in the upper view. A fixed value of amplitude -60 dBm was obtained for the impulses between 65 and 75 kHz. A continuous wave signal was found at 55 kHz.

Figure 30 shows background noise at the 75 to 125 kHz frequencies. Two types of impulsive noise appear in the views. The first noise type consists of pairs of slanting lines extending from 75 kHz upward to 120 kHz. An inspection of the upper view shows two fixed amplitude levels associated with the two lines of each pair. The time intervals between pulses suggest that the first impulse of each pair was synchronous with one phase pair of the three-phase power system and the second impulse of each pair was associated with a second phase pair. The second pulse of each pair was the strongest set of pulses which formed the upper amplitude line in the upper view. The second type of noise in Figure 30 consisted of three distinct sets of hook- or z-shaped structures

also synchronized with the power line frequency. These signals were formed by an impulsive source whose trigger point on the line voltage waveshape varied with time.

Background noise in the 175 to 225 kHz band of frequencies is shown in Figure 31. The primary noise consisted of the hook- or z-shaped structures caused by impulsive sources whose trigger point on the power line voltage waveshape varied with time.

### 3.6.3 System Measurements

Measurements were made on Feeder 14111 at the Greenleaf Avenue site to search for impulsive noise associated with WMATA train operation. A number of train runs were monitored with various capacitor bank configurations. Measurements were also taken on background noise as the capacitor banks were switched.

The WMATA train was operated with all capacitor banks out. During this run instrumentation parameters were adjusted to optimize the definition of weak impulsive noise. Post-measurement analysis of the data suggested that intermodulation problems were encountered from excessive wideband noise levels. Thus, the data were discarded, and useful data were not obtained when all capacitor banks were open.

Figure 32 shows background noise with the train stopped, all capacitor banks out, and as the 600 kVAR Kenilworth and Frolick bank on Feeder 14111 was switched in. A brief noise transient occurred at the instant of capacitor switching; however, no significant change in background noise was found. The data in Figure 32 were taken with the instrumentation connected to the McGraw-Edison 1000 to 1 voltage divider which was directly connected to Phase A of the distribution line. Equivalent data were not taken with the loopstick antenna because of the lack of sufficient time to readjust instrumentation parameters for repeat runs.

The train was operated with the instrumentation connected in the configuration used for Figure 32 and with the Kenilworth and Frolick 600 kVAR capacitor bank in. Instrumentation adjustments made to optimize the detection of impulsive noise again resulted in questionable data.

In the top view of Figure 33 the 12 MVAR Tuxedo substation capacitor bank was switched in. A switching transient was found, but no significant change occurred in the background noise level. In the bottom view of Figure 33 the 12 MVAR Tuxedo substation capacitor bank was in and the

train was started. No significant changes in noise level were noted. The data in Figure 33 were also taken with the instrumentation connected directly to the McGraw-Edison 1000 to 1 voltage divider.

Additional data were collected as the 1200 kVAR capacitor bank on Feeder 14111 was switched in and as the train was operated with this capacitor bank and with all other capacitor banks previously switched in. No changes in background noise were noted and train noise was not identified in the data.

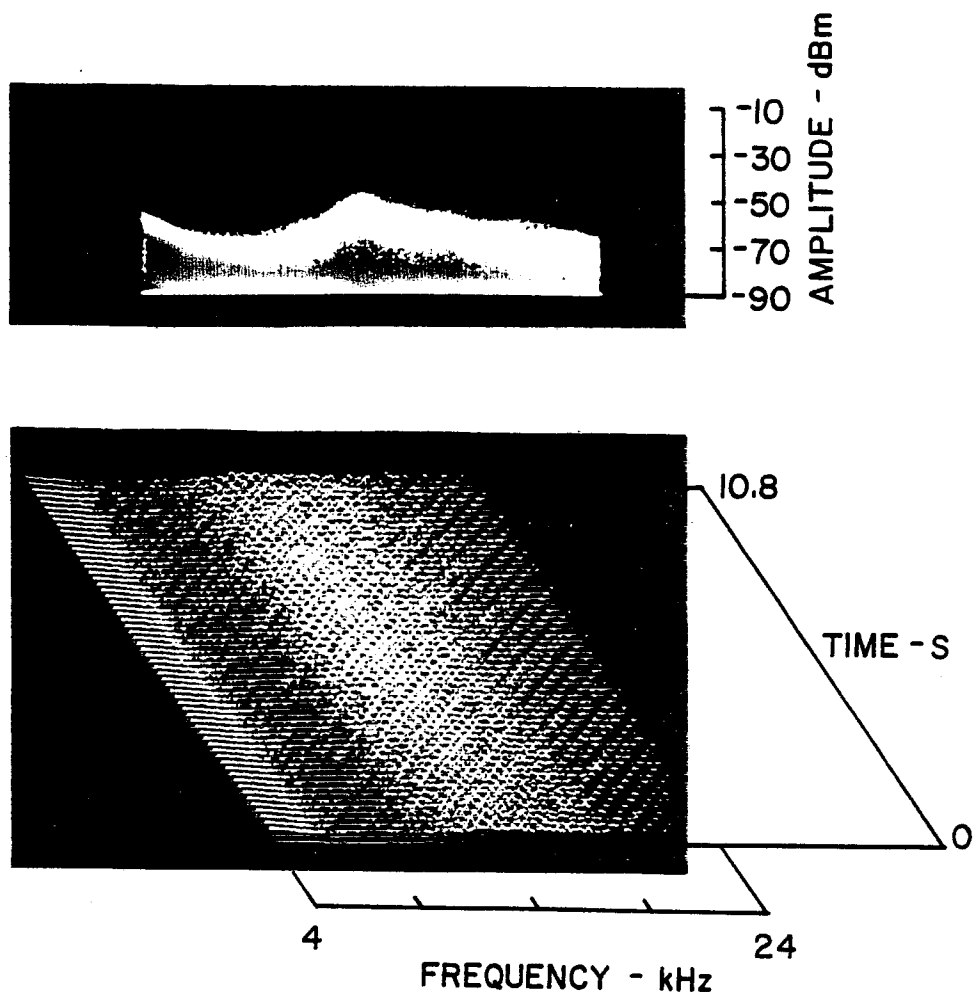


Figure 28 Greenleaf Avenue Site, 10/25/78, 0804

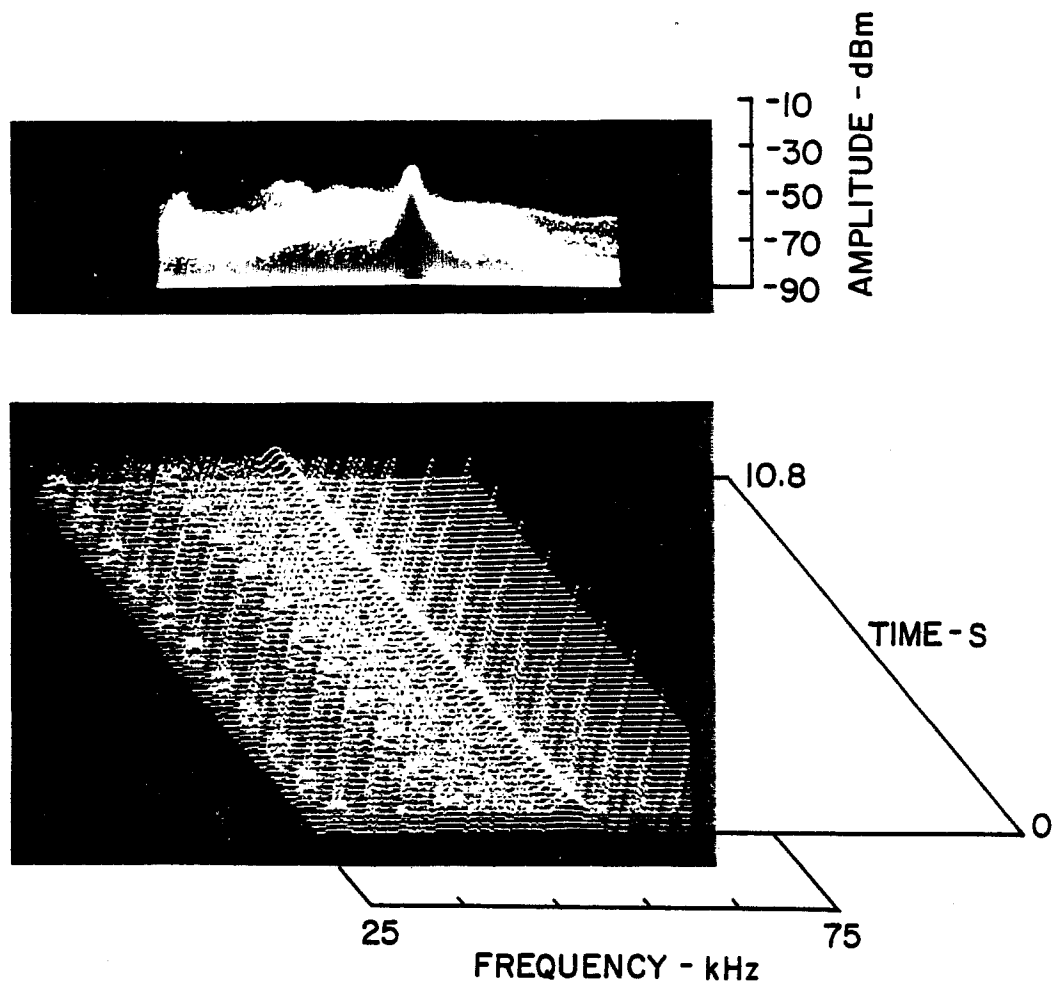


Figure 29 Greenleaf Avenue Site, 10/25/78, 0809

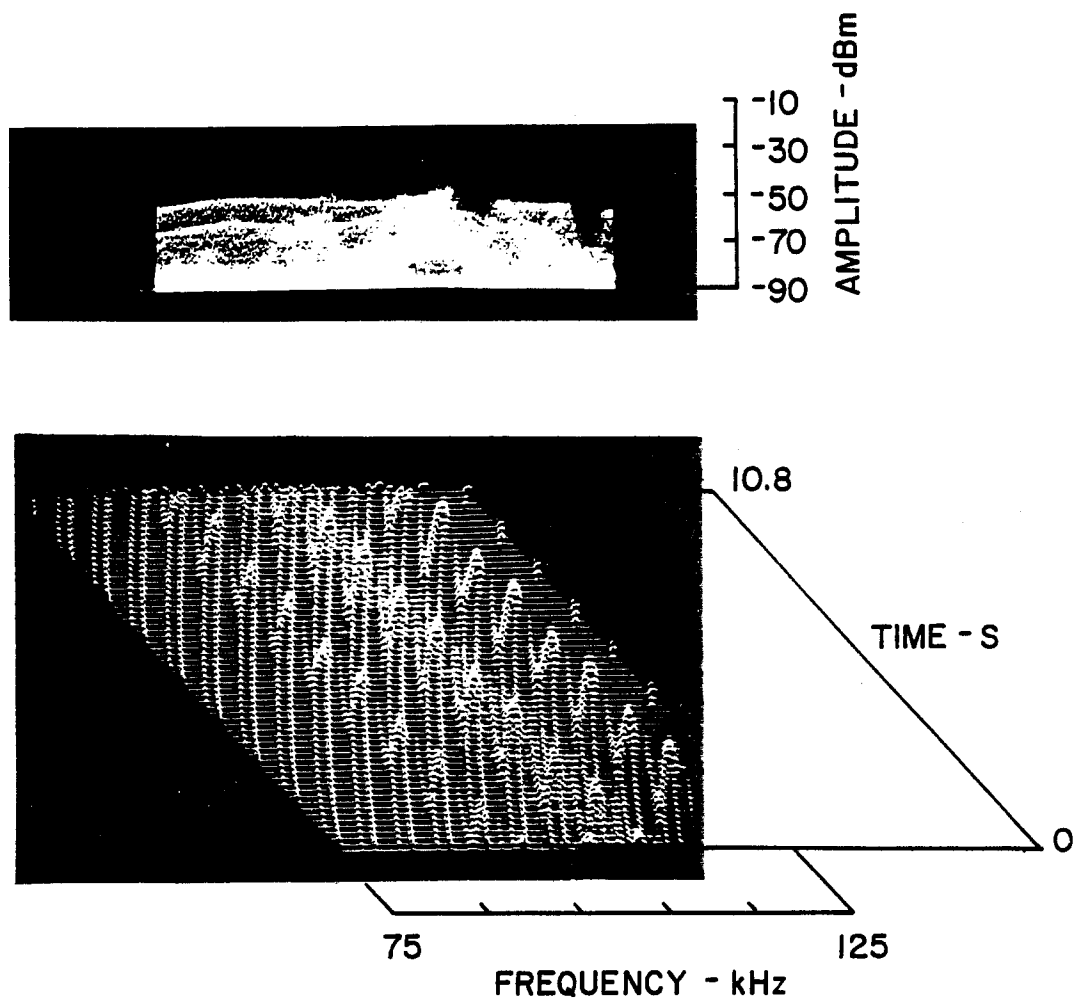
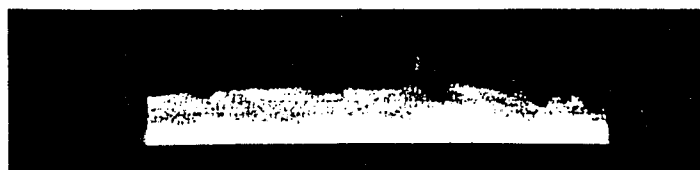
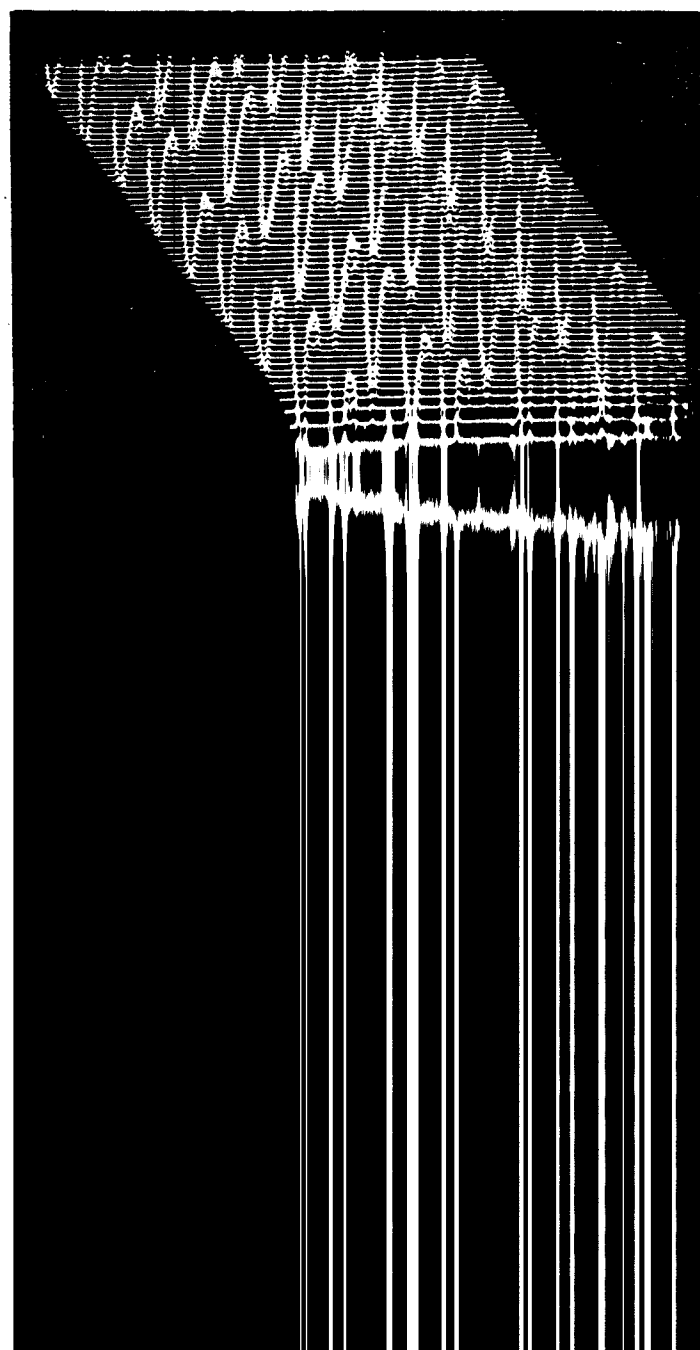


Figure 30 Greenleaf Avenue Site, 10/25/78, 0814



-10  
-30  
-50  
-70  
-90

AMPLITUDE - dBm



10.8

TIME - S

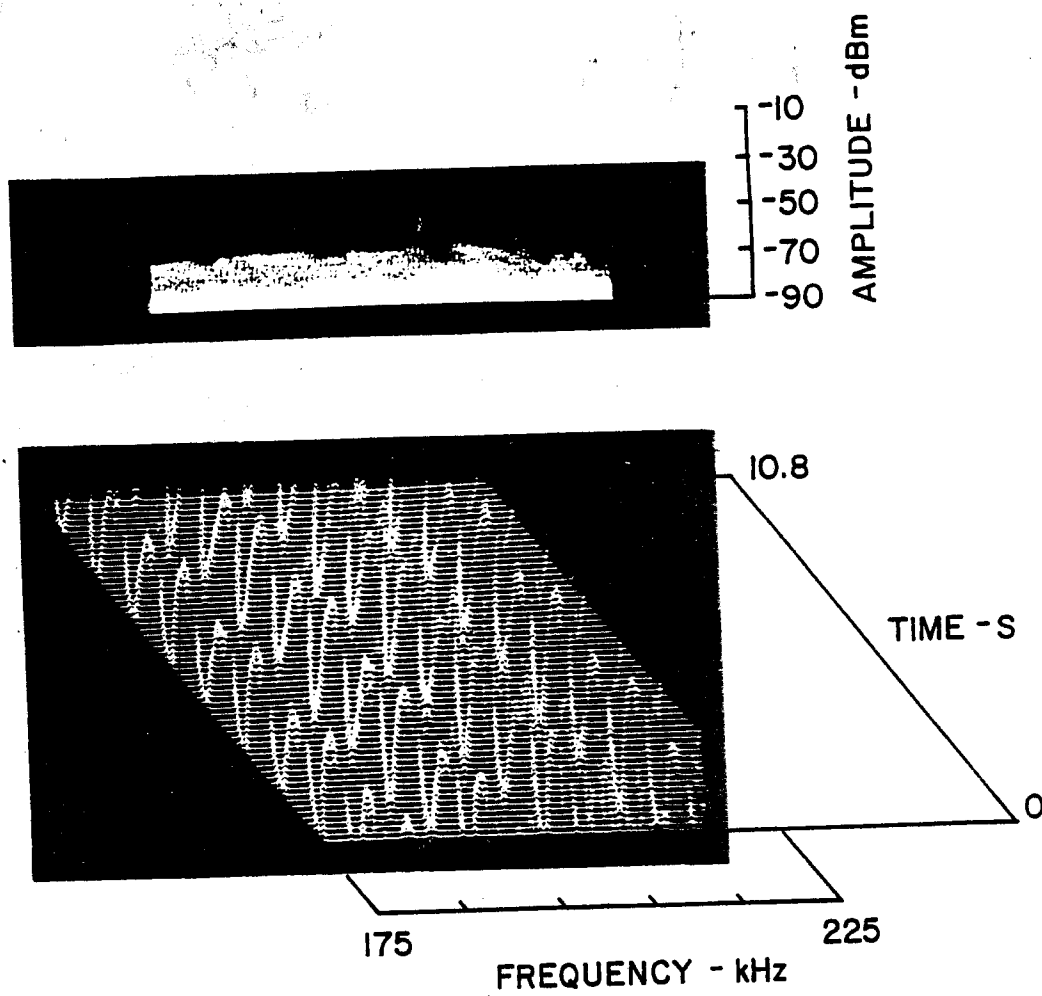


Figure 31 Greenleaf Avenue Site, 10/25/78, 0820

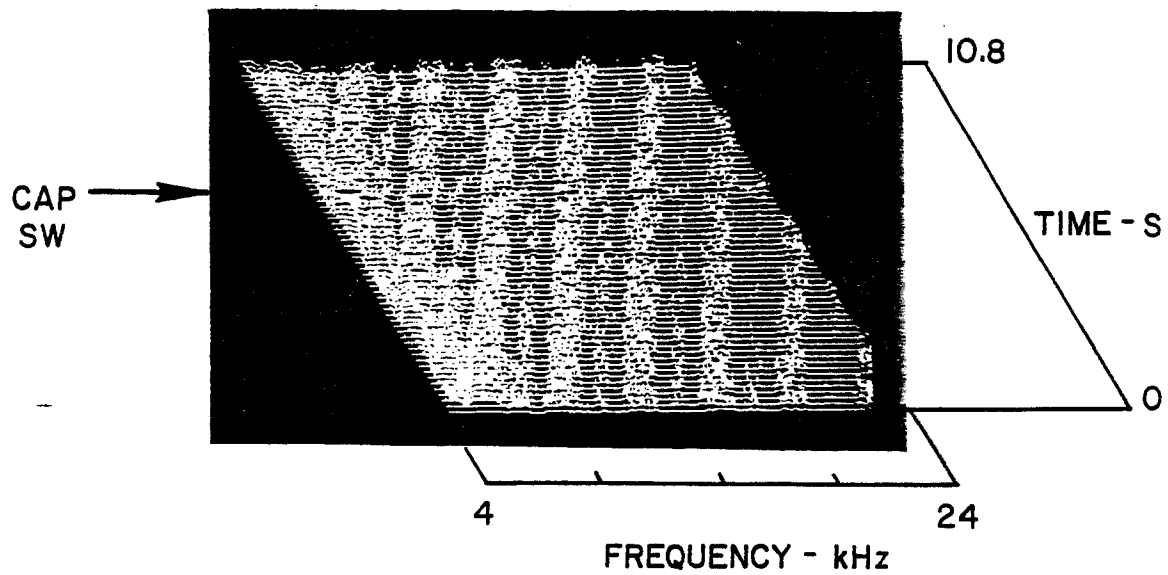
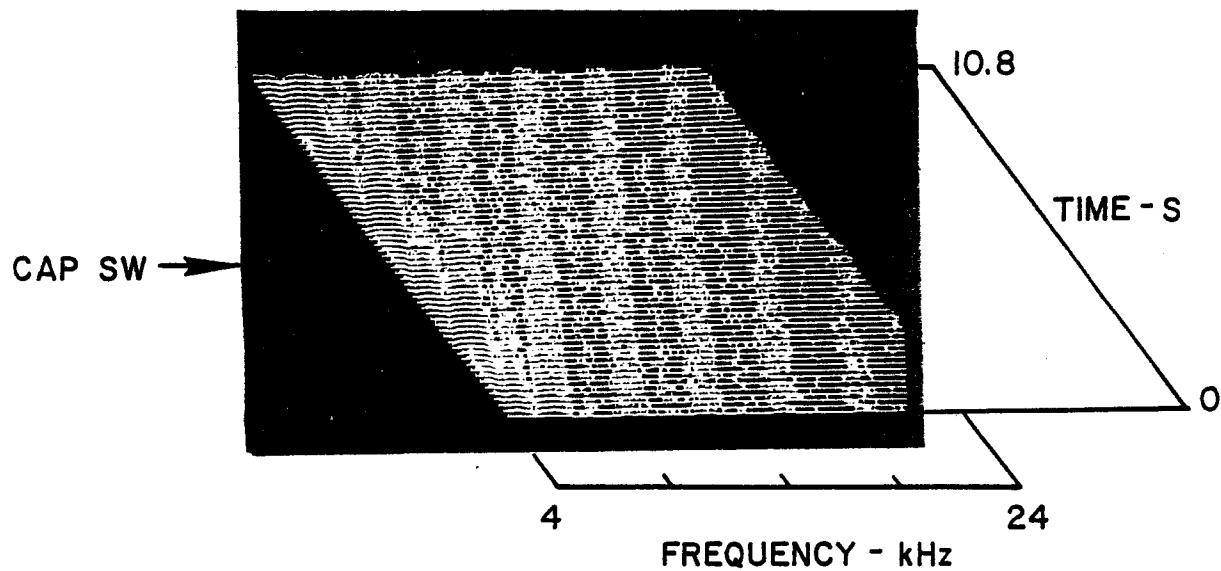


Figure 32 Greenleaf Avenue Site, 10/25/78, 0947

(a)



(b)

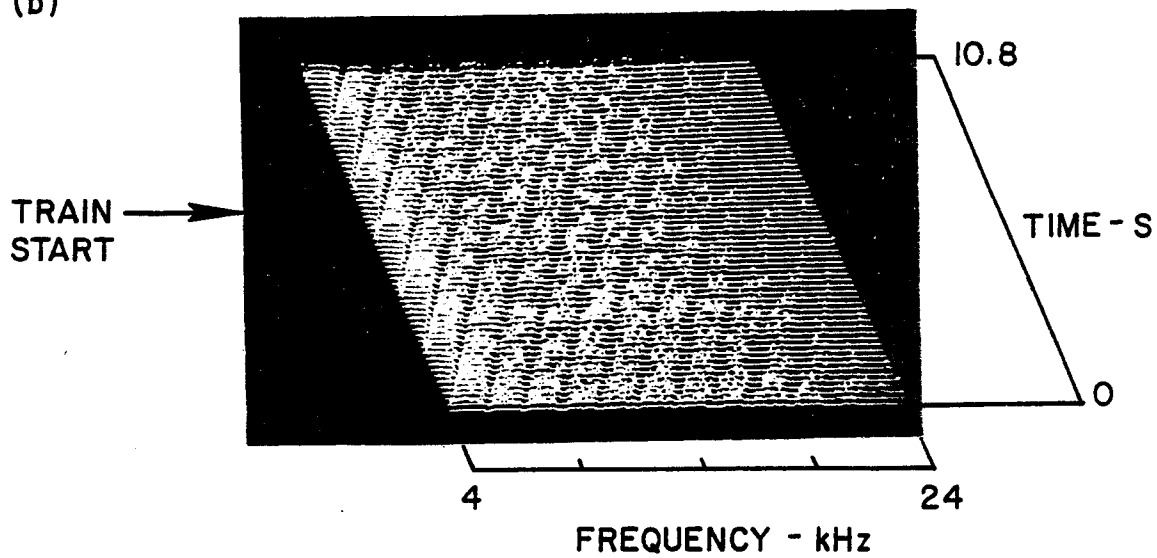


Figure 33 Greenleaf Avenue Site, 10/26/78, 1000

### 3.7 LANDOVER ROAD SITE

#### 3.7.1 Measurement Conditions

A site on Landover Road near the corner of Landover Road and Pinebrook was selected for the fifth set of measurements. The site was located on the side of a small regional park about two blocks from a small shopping center. A residential area of single family and duplex housing surrounded the small park.

The Landover Road site was on Feeder 14101 at a location 9.8 kft from the 14111 Riser Pole site. The measurement van was located directly under the 13.8 kV distribution line (Feeder 14111). Background measurements were made with a direct connection to the McGraw-Edison 1000 to 1 voltage divider connected to the roadside feeder pair (Phase A).

A log of the various actions taken during the Landover Road site measurements is given in Table 9. This log provides a convenient reference to the sequence of operations and the status of the PEPCO and WMATA systems. All data on system performance measurements provided in subsequent paragraphs can be related to this log.

Measurement system parameters for the various 3-axis views taken at the Landover Road site are summarized in Table 10. These parameters will be useful to those individuals who wish to scale the 3-axis views for some specific detail. The 3-axis views of WMATA/PEPCO systems measurements can be related to Tables 9 and 10 by date and time of day or with the figure number provided in each table.

Data was taken at the Landover Road site on 10/26/78 from about 1100 to 1500 hours local time.

Table 9  
LANDOVER ROAD SITE ACTIVITY

McGRAW-EDISON ITEM NO.	LOCAL TIME	DATE	CAPACITOR BANK STATUS	TRAIN STATUS	3-AXIS FIGURE NUMBER
33E	1230	10/26/78	All Cap. Banks Off	Train Run	39
34E	1246	10/26/78	1500 kVAR Cap. Bank on Feeder 14101 Switched In	Off	40(a)
35E	1305	10/26/78	1500 kVAR Cap. Bank Switched Off During Train Run	Train Run	40(b)
36E	1318	10/26/78	1200 kVAR Cap. Bank on Feeder 14101 Switched In (1500 kVAR Cap. Bank on Feeder 14101 Switched In Somewhat Later in Time)	Off	—
37E	1323	10/26/78	1200 kVAR and 1500 kVAR Cap. Banks on Feeder 14101 Both In and 1500 kVAR Bank Switched Off During Train Run	Train Run	41
38E	1341	10/26/78	12 MVAR Tuxedo Substation Cap. Bank Switched In	Off	—
39E	1353	10/26/78	12 MVAR Cap. Bank Switched Off During Train Run	Train Run	42
40E	1404	10/26/78	All Cap. Banks Off	Train Run	43
41E	1409	10/26/78	1200 kVAR Cap. Bank on Feeder 14101 Switched In	Off	—
42E	1416	10/26/78	1200 kVAR Cap. Bank In and Switched Off During Train Run	Train Run	44

Table 10  
MEASUREMENT SYSTEM PARAMETERS, LANDOVER ROAD

3-AXIS FIGURE NUMBER	DATE	LOCAL TIME	ANTENNA TYPE	LOOP FREQ. kHz	CENTER FREQUENCY kHz	FREQ. WIDTH kHz	IF BAND- WIDTH kHz	SCAN TIME ms	IF REF dB	RF REF dB
34	10/26/78	1147	Loop	10-40 T10	14	20	1	100	-10	0
35	10/26/78	1153	Loop	10-40 T40	50	20	1	100	-10	0
36	10/26/78	1159	Loop	50-150 T100	100	20	1	100	-10	0
37	10/26/78	1216	Loop	150-450 T150	150	50	1	100	-20	0
38	10/26/78	1227	Loop	150-450 T200	200	20	1	100	-20	0
39	10/26/78	1231	Loop	4-40 T10	14	20	1	100	-10	0
40(a)	10/26/78	1305	Phase A/V	—	9	10	1	100	-10	0
40(b)	10/26/78	1246	Phase A/V	—	9	10	1	100	-10	0
41	10/26/78	1330	Phase A/V	—	9	10	1	100	0	0
42	10/26/78	1355	Phase A/V	—	9	10	1	100	-10	20
43	10/26/78	1403	Phase A/V	—	9	10	1	100	-10	20
44	10/26/78	1415	Phase A/V	—	9	10	1	100	-10	20

### 3.7.2 Ambient Measurements

Background noise levels on Feeder 14101 at the Landover Road site were examined prior to WMATA train measurements. The rectifier was idled across the PEPCO system without train loads during these measurements.

Background noise at the 4 to 24 kHz frequencies was examined in Figure 34 using the loopstick antenna. Impulses synchronous with the power line frequency and with a period of 2.8 ms were found. Background noise conditions were similar to those found in Figure 17 at the P.G. Country Club site and in Figure 28 at the Greenleaf Avenue site.

In Figure 35 background noise was examined over the 40 to 60 kHz block of frequencies. From 40 to 55 kHz an impulsive noise with a period of 8 ms was found. In addition a time diffuse impulsive noise whose impulse time varied with respect to the 60 Hz line frequency was found centered at about 48 and again at 60 kHz. The structure of the time diffuse noise was somewhat similar to that at other sites, but the structural detail was sufficiently different to suggest that a new source was involved.

In Figure 36 background noise at the 90 to 110 kHz frequencies was examined. Low level impulsive noise synchronous with the power line frequency and with a period of 8.3 ms was found over the 90 to 105 kHz portion of the view. In addition a somewhat higher level and more time diffuse noise was found centered at about 100 kHz and again at about 110 kHz. These signals were formed by an impulsive source whose trigger point on the line voltage waveshape varied with time. The upper view of Figure 36 shows distinct amplitude structure associated with the two strongest impulse noise levels.

In Figure 37 background noise at the 125 to 175 kHz frequencies was examined. Two continuous wave signals were found at 135 and 142 kHz. Complex impulsive noise structure from several sources was found. The impulses were formed by sources whose trigger points on the line voltage waveshape varied with time. The resulting time domain properties of the impulsive noise were very complex at any selected frequency.

Background noise at the 190 to 210 kHz frequencies was examined in Figure 38. A primary impulse structure with a period of 8.3 ms can be found in the lower view. Additional impulse structure synchronized with the power line frequency was also found at lower amplitude levels. The resulting combination of impulse structures gave very closely spaced noise impulses which approached an impulse each 1 ms at some frequencies.

### 3.7.3 System Measurements

Measurements were made on Feeder 14101 at the Landover Road site to search for impulsive noise associated with WMATA train operation. A number of train runs were monitored with various capacitor bank configurations. Measurements were also taken of background noise as various capacitor banks were switched.

During the first measurement the WMATA train was operated with all capacitor banks out. Figure 39 shows noise levels observed before and after train start. No significant change was noted in the background noise. A very small additional noise component was noted in the 4 to 6 kHz portion of the view which appeared to be associated with train operation.

In the top view of Figure 40 the train was off, all capacitor banks were out, and the 1500 kVAR capacitor bank on Feeder 14101 was switched in at the time noted on the view. No significant change in background noise was noted at the time of the capacitor bank switching. A small increase in background noise noted about three seconds after the capacitor bank switching was an unrelated alteration of some source of the background noise.

In the bottom view of Figure 40 the train was running, the 1500 kVAR capacitor bank on Feeder 14101 was in at the start or top of the view, all other capacitor banks were out, and the 1500 kVAR bank was switched out at the indicated time. A switching transient was noted from the capacitor switch off action. Also, train noise increased in level and became quite visible in the view at 4 to 6 kHz from about 6 seconds downward to 0 seconds.

Both views of Figure 40 were taken with the instrumentation connected to the McGraw-Edison 1000 to 1 voltage divider. The voltage divider was connected to Phase A of the distribution line.

In Figure 41 the train was off, the 1200 kVAR capacitor bank on Feeder 14101 was in, all other capacitor banks were out, and the Tuxedo substation 12 MVAR capacitor bank was switched in at the time indicated in the bottom view. No change in background noise was found. A capacitor switching transient can be seen in the two views which exceeded the background noise amplitude by about 35 dB.

The two views in Figure 42 are identical except for threshold level adjustments necessary to highlight train noise structure. The 12 MVAR Tuxedo substation capacitor bank was in, all other capacitor banks were out, and the train was started at the time indicated in the views. Impulse structure associated with train operation was noted over the 4 to 6 kHz frequencies and from about 6 seconds (train start) down to 0 seconds. Instrumentation was connected to the McGraw-Edison 1000 to 1 voltage divider monitoring voltage effects on Phase A of distribution line.

In Figure 43 all capacitor banks were out and the train was started at the time indicated in the views. A distinct impulse signature associated with train operation was again noted in the 3-axis views. The view was taken with the instrumentation connected to the McGraw-Edison voltage divider monitoring voltage effects on Phase A. The views in Figure 43 can be compared with another view at a similar system operating configuration but with the instrumentation connected to a loopstick antenna (Figure 39). The direct connection monitoring voltage effects produced a more significant train noise signature than the loopstick which was related to current flow. In addition the background noise structure was very different for the voltage-based measurement (Figure 42) and for the current-based measurement (Figure 39). These observations are consistent with standing wave effects.